**RESEARCH PROGRESS OF THREE-DIMENSIONAL LASER SCANNING TECHNOLOGY IN SOIL AND WATER CONSERVATION AND DESERTIFICATION PREVENTION**

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**Abstract:** Three-dimensional laser scanning technology is a new method that has emerged in recent years for soil erosion monitoring, wind-sand landforms, and effectiveness evaluation of sand prevention measures. Soil and water conservation research and desertification prevention and control play an important role in promoting. This article reviews the previous use of three-dimensional laser scanning technology in soil and water conservation and desertification prevention and control work. The application in the work is summarized, and the current problems and follow-up research are discussed, with a view to providing suggestions for the further development and application of 3D laser scanning technology.

**Keywords:** 3D laser scanning technology; Soil erosion; Desertification; Outlook

**1 CURRENT RESEARCH STATUS IN THE FIELD OF SOIL AND WATER CONSERVATION**

Three-dimensional laser scanning technology is a technical method that relies on three-dimensional laser scanners to obtain ground spatial information at high spatiotemporal resolution [1]. Compared with traditional High-precision intelligent total station and 3D laser scanning technology can more quickly and accurately conduct multi-point measurements of various large, complex and irregular entities, and efficiently obtain the 3D coordinate data and color information of the measured target. and point cloud data, where point cloud data includes distance, angle, reflectivity and other values [2]. In recent years, domestic and foreign scholars’ research on 3D laser scanning technology has mainly focused on large-area topographic mapping. [3], Bridge deformation detection [4-6],establish Reconstruction of three-dimensional building models [7-8], mineralogy [9-11], botany [12] and many other fields, There are few reports on landslide and erosion gully stability monitoring, dune movement monitoring, and desertification prevention and control project benefit evaluation. The application of 3D laser scanners in soil and water conservation and desertification prevention is still in the growth stage. Although it has certain advantages, But at the same time, it is also affected by its own factors, which makes it have certain limitations in work. Therefore, in order to achieve better results in the future, Applying three-dimensional laser scanning technology to the research on soil and water conservation and desertification prevention and control. This article summarizes the application results of previous three-dimensional laser scanning technology in soil and water conservation and desertification prevention and control work.

The 3D laser scanner is a high-precision non-contact measuring instrument. A laser pulse diode is used to emit pulses, which are directed to the target through a rotating prism. The electronic scanning detector receives and records the returned pulses, and then the post-processing software converts the data into a model in the coordinate system. Its measurement error is small and can truly reflect the changes in surface characteristics of the measured object [13]. After data splicing, conversion and filtering to eliminate noise, it can describe the subtle changes in the surface of the measured object. characteristics [14]. The operation mode of the 3D laser scanner is simple and the scanning time is fast. The DEM (Digital Elevation Model, DEM) is generated from the measured point data.), Its highest accuracy can reach ± 3 mm [15], and the vertical measurement accuracy is ± 0.02 m [16]. Compared with traditional erosion probes and high-precision GPS monitoring methods, 3D laser scanner technology can better and more accurately describe the evolution process of surface erosion in a short time, and can even clearly show the corrosion caused by sheet erosion. Among the three measurement methods, the smallest erosion error estimated by the three-dimensional laser scanner is only 4.56%, and the error of high-precision GPS is between the other methods. 7.38%, the maximum error of the erosion probe method is 12.78% [17]. Based on the above-mentioned high-precision measurement principles and modes, Three-dimensional laser scanning technology has strong advantages in exploring the mechanism of erosion trenches. Multi-period high-precision DEM data obtained using three-dimensional laser scanning technology According to the data, not only can the differential study of gully slope erosion be carried out from the time scale and spatial scale, It can also describe and construct the development process of erosion gullies. mold. There have been certain research results in this area. For example, Xu Jiapan et al. used the method before and after rainfall to DEM Further analysis concluded that The bottom of the slope is mainly distributed with high- level slopes, and gully phenomena are prone to occur at the bottom of the slope [18]. Yu Shutong [19], Zhang Jiao [20] and others all used three-dimensional laser scanning technology to dynamically monitor and finely reveal the groove corrosion development process. Yang Chunxia et al. [21] used three-dimensional laser scanning technology to prove that the middle and lower parts of the slope surface and the middle part of the gully slope are the parts with the greatest erosion intensity in the slope and gully system. Qin Chao et al. used three-dimensional laser scanning technology to extract high-precision images under

intermittent artificial simulated rainfall conditions. DEM data, analysis results show that fine The maximum value of the gully erosion rate and the total erosion rate appears in the active period of rill development when the rill bottom incision erosion is the main one, and the minimum value appears in the early stage of the rill development when the gully head traceback erosion is the main one [22]. However, the use of three-dimensional laser scanning technology is greatly affected by weather. If surface data is measured during continuous rainfall, The field test cannot be observed due to the poor waterproofness of the machine itself. During indoor testing, raindrops from rainfall will become noise The difference between points and roughness will have a great impact on the subsequent point cloud data splicing modeling. Currently, there are many methods for point cloud denoising, which can be based on specific implementation. Choose an appropriate method to denoise according to the actual situation. For denoising during rainfall, point cloud layered denoising can be used [23] to delete independent noise points and non-ground points. The rest can be deleted manually in the software.

Three-dimensional laser scanner technology is not only used in the research of gully erosion and surface erosion, but also in the monitoring of collapse erosion, landslides, and debris flows. Foreign scholar Abell á n A It has been verified that this technology can be used as a reference tool for studying rock collapse, and the high-precision DEM obtained can record rockfall conditions and more accurately simulate the trajectory and speed of rockfalls [24]. Bengang erosion occurs in various ways, resulting in complex and diverse topography in the Bengang watershed [25]. And when using traditional methods to monitor collapsed hills, on the one hand, measurement is difficult; Monitoring personnel are unable to reach some places, and the measured data errors are quite large. For larger ones, On the other hand, during the observation process, monitoring personnel may be in a dangerous measurement environment, and personal safety cannot be guaranteed. Therefore, Liu Honghu and others found that three-dimensional laser scanning technology can overcome these difficulties, provide high-precision morphological characteristics data of collapsed hills, and analyze the channel development characteristics of collapsed hills [26]. Liu Xilin et al. used three-dimensional laser scanning technology to study the erosion process of collapsed hills. The results showed that: Topography is the main influencing factor in the development of collapsed hills. The erosion amount of collapsing hills and the change of surface slope of collapsing hills present a normal distribution [27]. Han Yongshun used three-dimensional laser scanning technology and high-resolution remote sensing images to monitor the surface deformation of flash floods, debris flow slopes, channels, sections and small watersheds under different rainfall conditions, and constructed a high-precision DEM, proposed the erosion, development and evolution characteristics of slope debris flows and channel debris flows, and revealed the deformation and damage, erosion and sedimentation changes and evolution rules of debris flows [28].

In summary, three-dimensional laser scanning technology has certain advantages in research on soil and water conservation. First, compared with traditional monitoring methods, three Dimensional laser scanning technology is highly accurate in obtaining data on the morphological changes of erosion trenches, and through reasonable data analysis, the changes in each part during the entire erosion process can be analyzed in detail, and an erosion model can also be established. Reflect the development process of erosion gullies more comprehensively and intuitively. Second, the measurement efficiency is high, high speed, This eliminates the need to consume a lot of labor and time in measuring large-area erosion ditches. Non-contact measurement also improves the performance of surveyors in field measurements. security.

Three-dimensional laser scanning technology also has certain limitations during its use. On the one hand, compared with the scanning measurement of buildings such as roads and bridges, there are no obvious landmark points in the scanning measurement of erosional landforms at different scales. The artificial placement of landmark points must be reasonably arranged based on the actual conditions of the study area and the requirements for later data processing. Otherwise, the workload will be increased. Later data splicing and verification are difficult. On the other hand, climatic factors (rainfall, wind) during the measurement process wait), Ground vegetation, telephone poles and other non-required objects, A large amount of unavoidable noise data will be generated. If reasonable denoising filtering is not performed, it will seriously affect the processing of later data results.

**2 CURRENT RESEARCH STATUS IN THE FIELD OF DESERTIFICATION MONITORING**

Desertification is currently a global ecological and environmental problem. It is very necessary to study the morphological changes and development and evolution characteristics of various wind-eroded landforms before setting up reasonable measures to prevent and control desertification. Currently, there are two methods for observing wind-sand landforms. Major categories: traditional monitoring research methods, modern monitoring research methods. Traditional monitoring research methods include written observation and recording methods and benchmark insertion methods. Modern monitoring research methods include 3S technology aerospace remote sensing measurement method, Terrestrial Differential GPS (RTK), total station and other methods [29], but these methods have certain limitations. Textual observation and recording method in developing sandstorm landforms When measuring, It is only suitable for small-scale quantitative research. It is difficult to obtain accurate data for large- and medium-scale measurements; the benchmarking method is affected by artificial errors. The sound is great, The measurement results are biased; although aerospace measurement can carry out large and medium-scale measurements, However, in the process of long-term dynamic monitoring, the cost is extremely high. high; During the operation of the total station, the host computer needs to maintain direct line of sight with the prism, which limits its monitoring of tall sand dunes and landforms; use RTK to measure Although the rover and reference station do not need to have direct line of sight, However, the morphological measurement of large-area sand dunes takes a long time and requires a large amount of work. At the same time, the measurement of leeward slopes is During the measurement process, it is difficult for the measurement personnel to walk. Reasons such as obstruction during the measurement process, strong magnetic field interference, and ultra-long distance measurement will cause the connection to lose lock, the measurement error and accuracy will be low, and the expected results will not be achieved. The 3D laser scanner is not affected by these natural and man-made factors. After multiple scans, it can be detailed and realistic The method of restoring the dynamic change process of wind-sand landforms has certain applicability to wind-sand micro-landforms. In research on desertification prevention and control, Especially the morphological changes in sand dunes It has very good application prospects in areas such as environmental protection and desertification prevention and control measures benefit evaluation. year 2004 Nagihara verified the feasibility of using a three-dimensional laser scanner to detect periodic changes in dune morphology [30]. Ochoa used three-dimensional laser scanning technology to study the geomorphological evolution of a sand dune [31]. Nield from 3D laser Start with scanning technology echo signal strength, By obtaining preliminary data on point clouds of sand grain transitions, combined with surface soil moisture and roughness, we elucidate the transition The importance of changes in the sand migration process, and this method was used to explore the movement and development of wind-sand belts on dry beaches. The results proved the potential use of three-dimensional laser scanning technology in studying wind-sand processes in beach and desert environments [32 -33]. Many domestic scholars have successively applied 3D laser scanners to desert areas. In different fields of desertification prevention and control, A series of important research results have been achieved, promoting the development of desertification research. Among them, in view of the harsh observation environment, texture Aeolian sand features with unclear characteristics (for example: sand dunes, Yadan bodies, etc.) , An Zhishan and others proposed a set of observation plans from field targets and measuring station layout to in-house data processing after summarizing the preliminary test applications and scientific exploration. At the same time, they compared with traditional total station measurements and finally determined There should be no more than 6 stations for measuring wind and sand features [34]. Zhang Qingyuan applied the three-dimensional laser scanner to the study of dune monitoring and analyzed the overall changes in the dunes by comparing the two monitoring results [35]. Ding Liangang used it to monitor the erosion pattern in the grass square sand barrier grid to obtain the high-precision erosion amount in the barrier grid. [36]. Zhang Kecun et al. used a three-dimensional laser scanner to evaluate the effectiveness of the sandstorm protection system along the Qinghai-Tibet Railway. The results showed that the vertical iron in the gravel grid It is easy to form a stable concave surface in the road direction. The sand fixation effect is remarkable, and the effective protection distance of the sand blocking fence is the height of the fence. 12 times [3 7].

**3 APPLICATION AND PROSPECTS OF 3D LASER SCANNING TECHNOLOGY**

Although three-dimensional laser scanning technology has been applied to a certain extent in soil and water conservation monitoring and desertification monitoring, But there is still a lot of room for development, especially in the changes in the morphological characteristics of various parts of the dune, the movement of the dune, and the development of erosion gullies.

(1) In subsequent research, coupled technologies should be coupled, such as monitoring of spatiotemporal dynamic changes in tall dense flowing sand dunes, to form a "3D laser scanner + The "UAV + GIS " monitoring system [38] combines the annual and seasonal three-dimensional morphological measurement of sand dunes with three-dimensional laser scanning technology and the large-scale multi-year aerospace measurement. In combination, if encountering the influence of clouds, scanning blind spots and other factors, small drones can be used for monitoring, and at the same time, it can be supplemented and verified with traditional ground measurement methods. It can more accurately provide certain data support for revealing the spatiotemporal dynamic changes of tall and dense flowing sand dunes. In modeling soil erosion landforms and sandstorm landforms, the results produced by a 3D laser scanner can be used DEM The morphological data is combined with the data calculated by the mathematical model to combine the digital model and the mathematical model. Use them together to select the optimal model and accurately describe and simulate the evolution mechanism of landforms.

(2) The problem of the instrument itself still needs to be solved, At present, Canada, Austria, the United States and other countries have already produced high- precision 3D laser scanners on a large scale [39]. Foreign countries have key technologies in 3D laser scanning technology and products. The formation of a technology monopoly makes 3D laser scanners expensive. not universal sex. At the same time, in order to meet the normal use of the instrument without DC power supply, the battery is designed to be heavy and large, which is difficult to use during field data collection. It is especially difficult to transport in the middle; some ground objects have poor sensitivity to the reflection of laser light sources. This causes blind spots to appear during the scanning process; After the measurement is completed, a huge amount of point cloud data is obtained, and ground vegetation will generate a large amount of unavoidable noise data. How to quickly denoise, effectively filter and process point cloud data is one of the current problems in the application of 3D laser scanners [40]. Therefore, it is necessary to strengthen research work in these aspects. In addition to optimizing and upgrading instruments and software supporting facilities themselves, instrument designers should cooperate with relevant scientific researchers to tackle key problems and carry out technological innovation. Break the technological monopoly, combine practical problems, and rationally design designed to meet current research needs.

**COMPETING INTERESTS**

The authors have no relevant financial or non-financial interests to disclose.

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